

TITLE: THE LASL GAMMA-RAY BURST ASTRONOMY PROGRAM

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SUBMITTED TO: Astrophysics and Space Science
(Proceedings of Conference on Cosmic
Gamma Ray Bursts, Toulouse, France,
November 25-30, 1979)

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The LASL Gamma-Ray Burst Astronomy Program

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Gamma-ray bursts were first reported from observations performed by the Vela satellites (Klebesadel et al., 1973). The events were identified from the Vela data primarily because of the rapid time variations resolved by the data recorded by the gamma-ray flux monitors included aboard the Vela satellites. The Vela 4 satellites, launched in 1967, were responsible for the initial observation of a single remarkable event. Vela 5 and Vela 6 satellites, launched in 1969 and 1970, acquired data which provided the evidence necessary to establish convincingly the validity of the observations.

The Vela observations allowed identification of these events because of the unique gamma-ray burst monitoring instrument employed. This system was designed to respond to rapidly increasing count rates in an array of scintillation detectors sensitive to photons (and energetic particles) depositing energy in the range 150 to 750 keV or 300 to 1500 keV. These data were recorded in an on-board memory, so that observations could be conducted nearly continuously and independently of telemetry monitoring. Simultaneous observation by identical instrumentation at widely spaced locations in a common 125,000 km circular geocentric orbit, and usually including locations both within and outside of earth's magnetosphere, allowed rejection of a local origin and confirmed the true nature of the events.

TABLE 1
VELA GAMMA BURST CATALOG

Date	Time UT-s	5		6	
		A	B	A	B
<hr/>					
-1969-					
690703	26233	X	X		
690719	13606		X		
691007	26790	X	X		
691008	59444	X	+		
691017A	11927	X	X		
691017B	78113	X	X		
-1970-					
700710	19066	X		X	
700822	60570	X		X	X
701001	56532	X			
701201	72059			X	X
701230	15337	X		X	X
-1971-					
710102	69056	X		X	X
710227	62857	X		X	
710315	40827	X	X	X	X
710318	55685	X		X	X
710421	11919	X	X		
710630	63059			X	X
-1972-					
720117	63556	X	X	X	
720312	57194	X	X	X	X
720328	49587	X	X		
720427	39512	+		X	
720514	13591	X		X	X
721101	68206	X		X	X
721113	55758				+
721118	73659			X	X
-1973-					
730125	54900	+			
730302	84475	+		X	X
730416	45550			+	
730507	29071	X		X	X
730606A	25648	X		+	
730606B	67630	X		X	
730610	75582	X		X	X
730721	32113	+		X	X
730725	61573	X		X	X
730918	18634	X		X	
730926	57890	+			
731217	29348	X			
731223	02387	X			
<hr/>					
Date	Time UT-s	5		6	
		A	B	A	B
<hr/>					
-1974-					
740121	67905	X			
740723	47488	X			
740929	67905	X			
-1975-					
751102	43518	X	X		
751202	86398	X	X	X	
-1976-					
760128	26969	X	X	X	
760322	55528	X	X	X	
760407	10464	X			
760419	26771	X			
760612	68618	X	X	X	
760816	58532	X			
760903	53400	X			
761123	68873	X			
761204	79853	+			
761209	03858	X	X	X	
761220	63511	X	X	X	
-1977-					
770107	79531	X		X	
770131	37764	X			
770310	38395	X			
770410	48447	X		X	
770501	76559	X			+
770708	46230	+			
771020	28495	X			
771029	42051	X			
771110	61967	X			
-1978-					
780508	72877	X			
780519	26509	X			
780521	78827	X			
780921	14165	X			
781104	58670	X	X	X	X
781119	44016	X	X	X	X
781124	14130	X			
-1979-					
790113	27198	X			
790305	57125	X	X	X	
790325	48293	X			

X denotes triggered response.
+ denotes real-time response.

The Vela satellites have recorded 73 gamma-ray bursts in the ten year interval from April 1969 through April 1979. Table 1 lists the events for which the Vela satellites have recorded data. The individual systems have responded with different efficiencies because of variations in sensitivities and transient instrumental and operational problems. Currently, all four of these systems are still supplying data useful in the investigations of gamma-ray bursts.

There existed a capability, through the good time resolution of the Vela data and moderately large separation between the satellites, for determining directions to the sources of the more intense bursts (those observed by three or four of the satellites) (Strong et al., 1974). These data were initially useful in rejecting the sun and other major members of the solar system as sources of the bursts. Although directional resolution is insufficient to allow identification of specific source objects, the distribution of these sources is nearly isotropic, suggesting a near galactic population or an extra-galactic origin. A marginally significant preference in the distribution toward the galactic equator suggested that a nearly galactic population was responsible for the bursts.

Upon publication of the Vela observations and through the cooperation and generosity of the Naval Research Laboratory we were able to include gamma-ray burst monitors aboard the NRL satellites SOLRAD 11A and 11B. This instrumentation was rather modest, since it was incorporated within contingencies for weight and power, at a late stage in the design. The instruments performed well but had a short life because of spacecraft thermal control problems. The two SOLRAD 11 spacecraft were launched April 1970. 11B telemetry transmissions ceased in December 1976, while the gamma burst instrument aboard 11A continued to operate sporadically until July 1977.

These instruments responded to a total of nine gamma-ray bursts. Of these, all were observed by at least one Vela, which was a criterion for verification of a candidate event. Four of the events were also observed by Helios-2. Event 761220 was the most intense event occurring in this period, and was observed by both Solrads, three Velas, and Helios-2. The event as recorded by Solrad 11B is shown in Fig. 1.

In response to a NASA request, LASL proposed a gamma-ray burst monitor to be included aboard the Pioneer Venus Orbiter spacecraft. The experiment was authorized in 1975 and was launched in May 1978. The instrument was placed in operation one day after launch and has served almost continuously since that time. During the same period we collaborated with UCB/Space Sciences Lab, providing the logics and memory necessary to utilize the ISEE-3 solar x-ray spectrometer as a gamma-ray burst monitor (Anderson et al., 1978). ISEE-3 was launched in August 1978, and it too has been serving nearly continuously since that time.

Both the Pioneer Venus and ISEE-3 instruments are in current operation fulfilling their mission. Another paper presented at this symposium (Evans et al., 1979) describes the Pioneer Venus instrument and results. The ISEE-3 gamma-ray burst experiment utilized signals derived from the x-ray spectrometer, shown in Fig. 2. A tantalum collimator is required to reduce the background counting rates in the energy range below ~ 100 keV from sources lying $>5^\circ$ beyond the plane of the ecliptic. The collimator was designed to minimize attenuation above 100 keV so as to provide, as nearly as possible with the given geometry, a uniformly omnidirectional response. The ISEE-3 instrument is somewhat less sensitive than Pioneer Venus because of a slightly smaller area and significantly higher energy threshold. Also, since there is a single

sensor, there is a higher potential for spin rate modulation for those sources located in the southern ecliptic hemisphere.

The ISEE-3 logics provide a capability of storing data in different modes, depending upon whether a response is determined to be caused by a gamma-ray burst or an x-ray burst from a solar flare. This determination is based upon the spectral distribution of the response. In the gamma-ray burst mode of operation count rate data in the full differential energy range $132 \leq E < 1250$ keV are accumulated in data samples recorded on a period of 11.7 ms. When the counting rate rises to a level such that 16 counts are accumulated within less than the 11.7 ms basic period, the time-to-spill, i.e., time required to attain this level of 16 counts (with resolution of $\sim 1/4$ ms) is recorded, rather than the level of accumulation. The data sample is presented as a 6 bit number, coded to avoid ambiguity between counts accumulated and time-to-spill. A single set of spectral data in six sub-intervals bounded by discrete thresholds at 132, 164, 228, 356, 484, 740, and 1250 keV is accumulated with each set of twelve samples in the full energy interval, comprising a data frame. While operating in the quiescent state, sixteen such frames are contained in a circular memory, preserving data representing the history of the detector response in the preceding 2.25 seconds.

The onset of an event is identified and high-resolution data acquisition is initiated by a "trigger" system based upon a logical comparison of counts in the full energy interval accumulated on periods of $1/4$, 1, and 2 s to logically constructed references which represent levels anticipated with a random probability of 10^{-6} or 10^{-8} (selectable upon command). When the trigger criterion is satisfied in any of these three channels, data acquisition into the experiment memory is initiated, and continues until the memory

is completely filled. The memory may be read out automatically, upon completion of the data acquisition cycle, or upon command, as a function of a command selectable option.

The ISEE-3 instrument has been in operation since August 1978. In that time, responses to 11 events were recorded as shown in Table 2 which tabulates the participation of LASL instrumentation in observations of verified events. Some ISEE-3 data were lost because of unscheduled telemetry outages. Generally, however, the efficiency in recording GRBs has been comparable to that of the Pioneer the Venus experiment.

It was our hope and our intention that we would be able to respond to the occurrence of gamma-ray bursts by providing directional analyses on a short time scale, alerting astronomers and allowing them to observe possible longer lived phenomena associated with the events. Such rapid reporting has been effected from the Vela satellites alone since 1974. However, operational and instrumental problems as well as a low frequency of events of intensity observable by available instruments precluded any significant real-time reporting in that early period. Also, the directional resolution available from the Vela data was insufficient to warrant searches with high resolution (and, consequently, small field) instruments.

Utilizing data acquired through full-time tracking of the ISEE-3 spacecraft and quick-look data from Pioneer Venus together with Vela data, we had hoped to be able to execute directional analyses quickly and with precision. Unfortunately, we discovered that ISEE-3 operations did not include active monitoring of the telemetry, and data were available routinely only from processed data tapes, with delays of six to eight weeks. Data were available more quickly, only upon specific request, through a procedure which required

TABLE 2
GAMMA RAY BURSTS OBSERVED BY LASL INSTRUMENTATION
INCLUDING HELIOS, PROGNOZ, AND SIGNE (VENERA) 11 AND 12 RESPONSES

Event	PV	IC	HB	P7	Signe		5A	5B	6A	6B
					11	12				
-1978-										
05/21	X		X				X			
09/14	X	X								
09/18		X			X					
09/21	X	X			X		X			
10/19	X	X				X				
11/04	X	X		X	X	X	X	X	X	X
11/15	X	X			X	X				
11/19	X	X	X	X	X	X	X	X	X	X
11/21	X			X		X				
11/24	X		X	X		X	X			
12/13	X		X	X			X			
-1979-										
01/13	X		X	X		X	X			
03/05	X	X	X	X	X	X	X	X	X	
03/07	X			X	X					
03/13	X					X				
03/25	X				X	X	X			
03/30	X	X				X				
04/06	X			X	X	X				
04/18	X	X		X	X	X				
04/19	X	X								
06/13	X				X	X				
06/26	X	X								

P = Pioneer Venus Orbiter

I = ISEE-3

HB = Helios-B

P7 = Prognoz 7

11 = Venera 11

12 = Venera 12

5A...6B = Vela 5A...Vela 6B

re-playing data logging tapes at the operations center and including the delays of transmitting data through the mails.

The availability of Pioneer Venus data also provided less than optimum conditions for rapid analyses and reporting. The computer based quick-look system was not implemented until orbital insertion on 1978 Dec. 4, and was supported only until 1979 Sept. 20. During the cruise phase of the mission previous to orbital insertion and presently we receive quick-look data through listings produced at the Pioneer Venus operations center located at the NASA/Ames Research Center. Telephone notification of the event flag condition is also provided. However, the current frequency of events triggered by solar activity discourages attempts to expedite data transmission through extraordinary means.

Additionally, fully processed data have been made available only since June 1979. These data were required to characterize the operation of the instrument, particularly to calibrate the clock and to establish the actual sensitivity at which the sensors are operating. These data also provide full coverage, including some events which were not recovered through the quick-look system.

In all, we were disappointed by our lack of a capability to respond rapidly to events. We continue to believe that such rapid response is a worthy goal, but achieving that goal through the present techniques of triangulation from widely spaced platforms would require a greater commitment on the part of those responsible for program operations. Perhaps a better technique, but one requiring a considerably greater investment in development and instrumentation, is imaging the source with a system having inherent directional resolution.

With fully processed data available, however, we are capable of contributing toward the primary objectives of these instruments: the precise determination of directions to gamma-ray burst sources. Approximately 20 events presenting a potential for reasonably precise locations have already been identified with a number of additional candidates as yet unverified. Further, the instruments contributing toward these measurements remain in good health, and may be expected to continue to provide observations.

The ultimate precision in directional determinations will require cooperative analyses of data from all members of the array of gamma-ray burst monitors. The primary goal of this meeting is that of furthering such cooperation. We hope that the interchange will promote that goal through improved mutual understanding of the various instruments involved.

Acknowledgment

This work was performed under the auspices of the U.S. Department of Energy.

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Figure Captions

Fig. 1. The gamma-ray burst event of 76/12/20 as recorded by SOLRAD 11B.

Fig. 2. The configuration of the sensor of the ISEE-3 Solar X-Ray Spectrometer/Gamma Burst Detector.



